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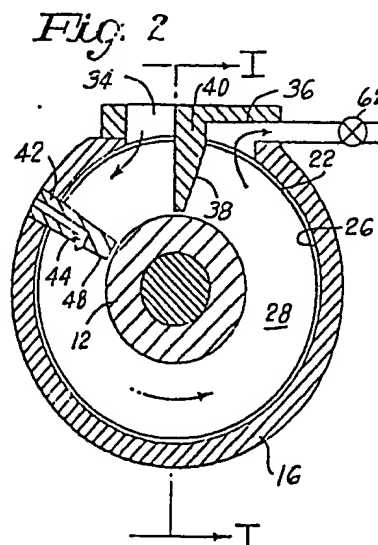
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**(54) Methods and apparatus for mixing liquid with viscous material.**

(57) The invention relates to rotary processors and methods for mixing low viscosity liquid with viscous material while controlling plugging of the means for introducing the low viscosity liquid. A mixing rotary processor (10) comprises at least one annular channel (18) on a rotor (12) enclosed by a housing (16) for form a mixing passage (28) into which a viscous material is introduced and dragged forward by the rotating channel walls (20) from an inlet (34) past a spreader (42) as films on the channel walls, forming a void downstream of the spreader (42) between the films. Low viscosity liquid is sprayed by spray means (44) within the void on to and carried downstream with the films to be mixed with material collected at a passage end wall (38).

Conveniently spraying is into a saturated vapor zone in the void where liquid vaporizes and condenses onto the films as well distributed fine droplets.

Removal of impurities which are devolatilised only with difficulty is facilitated.



1     METHODS AND APPARATUS FOR MIXING LIQUID WITH VISCOUS  
      MATERIAL

      This invention relates to novel methods and  
      apparatus for processing viscous materials and  
5     particularly to rotary processors and methods for mixing  
      low viscosity liquids with viscous materials

      Rotary processors are known to the art.  
      Details relating to such processors are described in U.S.  
      Patents Nos. 4,142,805; 4,194,841; 4,207,004; 4,213,709;  
10    4,227,816; 4,255,059; 4,289,319; 4,300,842; 4,329,065;  
      4,389,119, 4,402,616; 4,411,532; 4,413,913; 4,421,412 and  
      in our copending U.K. Patent Applications Serial Nos.  
      2,147,221, 2,147,219, 2,147,222, 2,147,220 and 2,146,916.

      Essential elements of the basic individual  
15    processing passage of rotary processors disclosed in the  
      above Patents and Applications comprise a rotatable  
      element carrying at least one processing channel and a  
      stationary element providing a coaxial closure surface  
      forming with the channel an enclosed processing passage.  
20    The stationary element provides a feed inlet and a  
      discharge outlet for the passage. A stationary blocking  
      member near the outlet provides an end wall surface to  
      block movement of material fed to the passage and to  
      coact with the moving channel walls to establish relative  
25    movement between the blocked material and the moving  
      channel walls. This coaction permits material in contact  
      with the moving walls to be dragged forward to the end  
      wall surface for collection and/or controlled processing,  
      and discharge. As disclosed in the above Patents and  
30    Applications, the processing passages present a highly  
      versatile processing capability. Patent 4,421,412  
      discloses apparatus for melting particulate materials,  
      and includes means for improving mixing of melted and  
      unmelted material to increase the melting efficiency of  
35    the processor. Patents 4,142,805 and 4,194,841 disclose  
      in one embodiment apparatus and methods providing a

1 mixing dam extending part way into the channel between  
the inlet and the outlet to improve mixing by increasing  
the shearing action on the material in the passage. A  
port may be provided through the housing downstream of  
5 the dam to remove material from or add material to a void  
created downstream of the dam. However, none of these  
patents discloses or claims apparatus or methods for  
introducing a low-viscosity material to a a mixing  
passage for improved mixing with a viscous material.

10 Patents 4,255,059; 4,329,065 and 4,413,913  
relate to apparatus and methods for devolatilizing  
viscous materials by spreading the material as thin films  
on the sides of the rotating channel walls so that  
volatile materials can be withdrawn from the surfaces of  
15 the thin films. Applications Serial Nos. 2,147,222 and  
2,146,916 disclose apparatus and methods for foam  
devolatilizing of viscous materials involving feeding the  
material to the processing passage, inducing foaming by  
formation of bubbles of volatiles and non-pressurizing  
20 shearing to release the volatiles for removal from the  
the passage. Application No. 2,147,221 discloses a  
vacuum system for use with either film or foam  
devolatilizers. Applications Nos. 2,147,219 and  
2,147,220 disclose sealing means to control leakage of  
25 pressure (e.g. while operating under high vacuum) and  
material between processing passages at different  
pressure levels. Patents 4,207,004; 4,289,319 and  
4,300,842 disclose rotary processor seals to resist flow  
of liquid material into the clearance between the housing  
30 and the rotor.

U.S. Patent No 3,267,075 discloses a method for  
removing solvents used in the production of  
polycarbonates to obtain pure polycarbonate from a dilute  
solution containing from about 2% to about 30-40%  
35 polycarbonate. The method comprises heating the dilute  
solution to at least the boiling point of the solvent,

1 volatilizing a portion of the solvent, mixing with the  
remaining solution using known equipment and procedures a  
devolatilizing aid comprising a chemically inert material  
having a boiling point below the decomposition  
5 temperature of the polycarbonate and heating this mixture  
to volatilize the remaining solvent and impurities. The  
polycarbonate may then be extruded as a purified product.  
In a preferred embodiment, these steps are carried out in  
a single multi-section screw extruder.

10 U.S. Patents 3,799,234 and 3,963,558 disclose  
apparatus and methods for removing dissolved solvent from  
polymers in multi-stage screw extruder-devolatilizers.  
Patent 3,799,234 discloses a sealed stage of the extruder  
for injecting a gas such as steam for countercurrent flow  
15 to strip volatile components from the polymer, the major  
portion of the injected gas being removed upstream of the  
point of injection. Also disclosed in the patent is a  
provision for injecting water into the material to cool  
the polymer at a point downstream of a pressure seal  
20 isolating the upstream injection section. This water is  
removed as a vapor through an additional vent positioned  
between the water injection point and the steam injection  
section. Patent No. 3,963,558 discloses as one of the  
final steps in purifying the polymer injecting for  
25 countercurrent flow a stripping fluid which is removed as  
a vapor upstream of the introduction point. More than  
one fluid injection section may be provided, each section  
being separated by a pressure seal.

However, addition and dispersion of a low  
30 viscosity liquid, such as a carrier to aid  
devolatilization, to a viscous material such as a polymer  
melt, as is described in above Patents 3,267,075;  
3,799,234 and 3,963,558, usually involves injection of  
the low viscosity liquid directly into the pressurized  
35 viscous material at a relatively high processing

1 temperature. The injected liquid experiences back  
pressure from the viscous material as droplets or  
globules of liquid are being formed at the outlet of the  
injection means. This back pressure can result in  
5 injection rate control difficulties and plugging of the  
injection outlet by the viscous material. In particular,  
addition of low viscosity devolatilizing aids and  
subsequent devolatilization may require multi-section  
devolatilizing screws of extensive length and high energy  
10 input.

This invention presents to the art novel rotary  
processors and methods for simply, efficiently and  
thoroughly mixing low viscosity liquids with viscous  
materials.

15 The novel processors and methods of this  
invention provide improved mixing of low viscosity  
liquids with viscous liquid materials while controlling  
plugging of the means for introducing low viscosity  
liquid to the processor. The mixing methods and  
20 apparatus of the present invention involve a rotary  
mixing processor comprising one or more annular channels  
carried by a rotor and enclosed by a housing to form  
mixing passages. Each passage has an inlet, a member  
providing a passage end wall spaced apart from the inlet  
25 and an outlet near the end wall. Viscous material fed to  
the inlet is dragged forward by the rotating side walls  
of the channel toward the end wall before collection as a  
recirculating pool, mixing, and discharge from the  
passage. A spreader extends into the channel at a point  
30 between the inlet and the end wall to spread viscous  
material on the rotating side walls of each mixing  
passage as films, forming a void between the films.  
Spray means are provided within the void, preferably at a  
downstream surface of the spreader, to introduce low  
35 viscosity liquid to the passage. In one embodiment of  
the invention, the liquid is sprayed onto the films of

1 material to be carried downstream with the films for  
mixing with the viscous material at the end wall.

In a preferred embodiment, a mixing passage is  
utilized to purify a viscous material containing one or  
5 more difficultly devolatilizable impurities by mixing  
with the viscous material a low boiling liquid selected  
to serve as a devolatilizing aid to form a homogeneous  
mixture from which the devolatilizing aid and the  
impurities may be devolatilized.

10 In another, especially preferred embodiment,  
sealing means are provided to prevent leakage of  
pressurized vapors of the volatile materials through the  
clearance between the rotor and the closure surface of  
the housing. This sealing permits buildup of the partial  
15 pressure of the vapor in the void between the films on  
the sidewalls to a level substantially equal to the vapor  
pressure of the low viscosity liquid at the processing  
temperature, forming a saturated vapor zone in the void.  
As additional low viscosity liquid is introduced to the  
20 saturated vapor zone, the vapor condenses on the films as  
well distributed, fine droplets, the size and  
distribution of the droplets being independent of the  
nozzle geometry. Thus, improved mixing may be achieved  
using ordinary spray nozzles, as a result of improved  
25 distribution. The well distributed, low viscosity liquid  
is then intimately mixed at the recirculating pool at the  
end wall.

In an alternate arrangement, the recirculating  
pool may be collected and mixed at a point upstream of  
30 the end wall by providing an additional spreader or a  
blocking member at a point between the first spreader and  
the end wall.

Details relating to the novel mixing apparatus  
and methods of the invention as well as the advantages  
35 derived therefrom will be more fully appreciated from the  
following detailed description of preferred embodiments

1 of the invention to be read with reference to the accompanying drawings.

Figure 1 is a simplified cross-sectional view of a mixing processor embodying the invention, taken  
5 along line I-I of Figure 2;

Figure 2 is simplified cross-sectional view of the processor of Figure 1 taken along the line II-II of Figure 1 ;

Figure 3 is a simplified schematic view of  
10 processing passages of the processor of Figure 1, with arrows indicating the flow direction of material through each passage, and schematically illustrating spray means for introducing low viscosity liquid to the passage;

Figure 4 is a simplified cross-sectional view  
15 similar to Figure 2 of an alternate arrangement of a processing passage embodying the invention.

Referring first to Figures 1-3, novel mixing processor 10 of one embodiment of the invention includes rotor 12 mounted on drive shaft 14 for rotation within a  
20 stationary element comprising housing 16. Rotor 12 carries mixing channels 18 each having opposed side walls 20 extending inwardly from rotor surface 22. Means 24 for rotating rotor 12 may be of any suitable type commonly used for rotating extruders or similar  
25 processing apparatus and are well known to those skilled in the art. Housing 16 provides coaxial closure surface 26 cooperatively arranged with surface 22 of rotor 12 to form with channels 18 enclosed mixing passages 28, 30 and 32. Representative passage 28, as shown in Figure 2,  
30 includes inlet 34 and outlet 36, formed in housing 16. Stationary member 40, associated with housing 16, fits closely within channel 18 and provides end wall 38 for the passage.

In operation viscous liquid material entering  
35 the passage through inlet 34 is dragged by rotating side walls 20 toward end wall 38 for collection as a

1 recirculating pool and pressurization induced by the  
continued rotation of side walls 20 past the pool for  
discharge from the passage through outlet 36. The  
pressurization of viscous material at the stationary end  
5 wall of a rotating annular channel and the discharge  
through an outlet is described in detail in Patents  
4,142,805 and 4,194,841, referenced above.

Figures 2 and 3 illustrate means according to  
the invention for introducing low viscosity liquid to the  
10 passage for mixing with the viscous material. Spreader  
42, associated with housing 16, extends into channel 18  
to block at least some of the material entering passage  
28 and spread the material dragged past the spreader onto  
side walls 20 of the passage to be carried toward end  
15 wall 38 as films 52 on the side walls, creating void 43  
between the films and downstream of spreader 42. Spray  
means 44 for introducing solvent liquid to the passage  
from a point within the void is illustrated in Figures 2  
and 3 as a conventional conduit and spray nozzle assembly  
20 arranged to receive low viscosity liquid from supply  
means 46, normally positioned outside of the housing. In  
a preferred arrangement, spray means 44 is carried by  
spreader 42 with the spray nozzle positioned within void  
43 at or near downstream surface 48 of spreader 42. In  
25 operation, as illustrated in Figure 3, viscous material  
entering the passage at inlet 34 is collected upstream of  
spreader 42 and is spread as films 52 on rotating side  
walls 20 of the passage, creating void 43 downstream of  
the spreader. Low viscosity liquid from supply means 46  
30 is introduced to the passage through spray means 44 and  
is sprayed onto films 52 from a point within void 43, as  
shown at 54, thus avoiding plugging of the spray nozzle  
by back pressure from the viscous material. The sprayed  
liquid is carried with films 52 toward end wall 38 to be  
35 collected with the viscous material as recirculating pool  
58. In pool 58 a vigorous mixing action is effected, as



1 shown by arrows 60, by the continued rotation of side  
walls 20 past the recirculating pool. This mixing action  
finely disperses and/or dissolves the low viscosity  
liquid in the viscous material. The mixture of viscous  
5 material and low viscosity liquid is pressurized for  
discharge from the passage through the outlet, as  
described above.

Outlet control means such as valve 62, shown in  
Figure 2, may be used to control the size of  
10 recirculating pool 58 and thus the angular position of  
pool boundary 64, shown in Figure 3, also affecting the  
residence time, temperature and discharge pressure, and  
controlling the extent of mixing of the low viscosity  
liquid in the viscous material in recirculating pool 58.  
15 Also, although continuous operation of the processor is  
normally preferred, valve 62 may be used to effect batch  
processing if desired by closing valve 62 during  
processing and opening the valve for discharge of the  
processed material.

20 Preferably, sealing means such as seals 66  
(Figure 1) are provided, e.g. on rotor surface 22, to  
prevent leakage of pressurized viscous material from the  
passage through the clearance between rotor surface 22  
and closure surface 26. The temperature of the material  
25 within the passages may be controlled such as by  
temperature control means 68 (Figure 1), which is a  
series of chambers within rotor 12 and/or elsewhere in  
the processor, through which a heat transfer fluid may be  
circulated in known manner to provide heating or cooling  
30 of the material in the passages. Details relating to  
examples of suitable sealing means 66 and heating means  
68 can be found in U.S. Patents 4,142,805; 4,194,841;  
4,207,004; 4,289,319 and 4,300,842, referenced above and  
incorporated herein by reference.

35 An especially preferred embodiment provides  
improved control of the processing conditions and

1 improved mixing of low viscosity liquid and viscous  
material using ordinary spray nozzles. In this  
embodiment, seals 66 comprise pressure seals to control  
5 viscosity liquid as well as viscous material through the  
clearance between rotor surface 22 and closure surface  
26. Suitable pressure seals are disclosed in  
Applications 2,147,219 and 2,147,220, referenced above  
and incorporated herein by reference. Such pressure  
10 seals permit establishment of a saturated vapor zone  
within the void between films 52 on the side walls and  
between spreader 42 and pool boundary 64. Spreader 42  
and pool 58 aid sealing of the saturated vapor zone by  
providing liquid seals to prevent pressure leakage from  
15 the void to upstream and/or downstream portions of the  
passage.

In operation, viscous material being dragged  
past spreader 42 forms a liquid seal preventing upstream  
leakage of pressurized vapors past the spreader. The  
20 spreading of viscous material on the moving walls creates  
void 43 downstream of the spreader between the films of  
material. Upstream boundary 64 of recirculating pool 58  
defines the downstream extent of the void while pool 58  
itself forms a liquid seal preventing downstream leakage  
25 of pressurized vapors. The pressure seals described in  
Applications 2,147,219 and 2,147,220 control vapor  
leakage through the clearances between surfaces 22 and  
26, providing a zone capable of containing pressurized  
vapors. Cooled low viscosity liquid is introduced to the  
30 passage through spray means 44 in the manner described  
above at a pressure near the vapor pressure of the liquid  
at the processing temperature and at a temperature lower  
than the processing temperature. The sprayed low  
viscosity liquid partially vaporizes into void 43.  
35 Sealing of the vapor zone permits buildup of the partial  
pressure of the vapor in the void to a level

1 substantially equal to the vapor pressure of the low  
viscosity liquid at the processing temperature, forming a  
saturated vapor zone in the void. As additional low  
viscosity liquid is introduced to the saturated vapor  
5 zone, the vapor condenses on the films as well  
distributed, fine droplets, the size and distribution of  
the droplets being independent of nozzle geometry. Thus  
improved mixing may be achieved using ordinary spray  
nozzles, as a result of improved distribution. The well  
10 distributed, low viscosity liquid is then intimately  
mixed at the recirculating pool at the end wall.

Processors according to the invention are  
especially suitable for addition of low boiling liquids  
such as carrier liquids or devolatilizing aids for  
15 removal of difficultly devolatilizable impurities from  
viscous materials. When operated as part of a  
devolatilizing apparatus, rotary mixing processors  
according to the invention may be arranged to spray or  
deposit onto films 52 of viscous material in the manner  
20 described above a low viscosity, low boiling carrier  
liquid. The carrier liquid is selected to act as a  
devolatilizing aid to remove one or more of the  
difficulty devolatilizable impurities contained in the  
viscous material. The proportion of carrier liquid  
25 relative to the material is selected to be sufficient to  
remove at least a portion of the impurities contained in  
the material. Following the mixing of carrier liquid and  
viscous material in the mixing passage, the mixture is  
devolatilized to separate the carrier liquid and at least  
30 a portion of the impurities from the viscous material.  
This mixing of carrier liquids with viscous materials may  
be carried out either by spraying liquid carrier onto  
films of material or, preferably, under saturated vapor  
conditions, as described above. Also, for further  
35 purification of some materials, the mixing and

1 devolatilizing steps may be repeated two or more times in series.

Rotary mixing processors according to the invention may have a single passage or a plurality of  
5 passages. Two or more passages may be arranged to operate in parallel as a single stage, each passage having an inlet to receive material from outside the processor and an outlet to discharge material from the processor, as illustrated in Figures 2 and 3 for passage  
10 28 of processor 10. Alternatively, the passages may be arranged to operate in series or in a combination of series and parallel operation, providing multi-stage operation for the apparatus.

For example, for some materials or for some  
15 processing conditions it may be desirable to introduce low viscosity liquid into the mixing passage and mix the liquid with the viscous material two or more times in series. Such an arrangement is shown schematically in Figure 3, in which mixing passages 30 and 32 of processor  
20 10 are interconnected by material transfer groove 80. Material transfer groove 80 is formed in the closure surface, extending from a point near end wall 38 of passage 30 to passage 32, and provides outlet 36a for passage 30 and inlet 34a for passage 32.

25 In operation, viscous liquid material is introduced to passage 30 at inlet 34 and is spread by spreader 42 as films 52 on side walls 20 of passage 30 to be carried toward end wall 38 for collection and mixing. Spray means 44 of passage 30 sprays low viscosity liquid  
30 from a point within void 43 to be deposited onto films 52 to be carried with the films toward end wall 38 and mixed with the viscous material in recirculating pool 58. The resulting mixture is pressurized for discharge through outlet 36a and transfer to passage 32 through material  
35 transfer groove 80.

1           The mixture enters passage 32 through inlet 34a  
and is spread by spreader 42 as films on side walls 20 of  
passage 32 to be carried toward end wall 38 for  
collection and mixing. Spray means 44 of passage 32  
5   sprays additional low viscosity liquid from a point  
within void 43 to be deposited onto films 52 of the  
mixture to be carried with the films toward end wall 38  
and dispersed in the viscous material in recirculating  
pool 58. The mixture of viscous material and low  
10 viscosity liquid is pressurized for discharge from  
passage 32 through outlet 36.

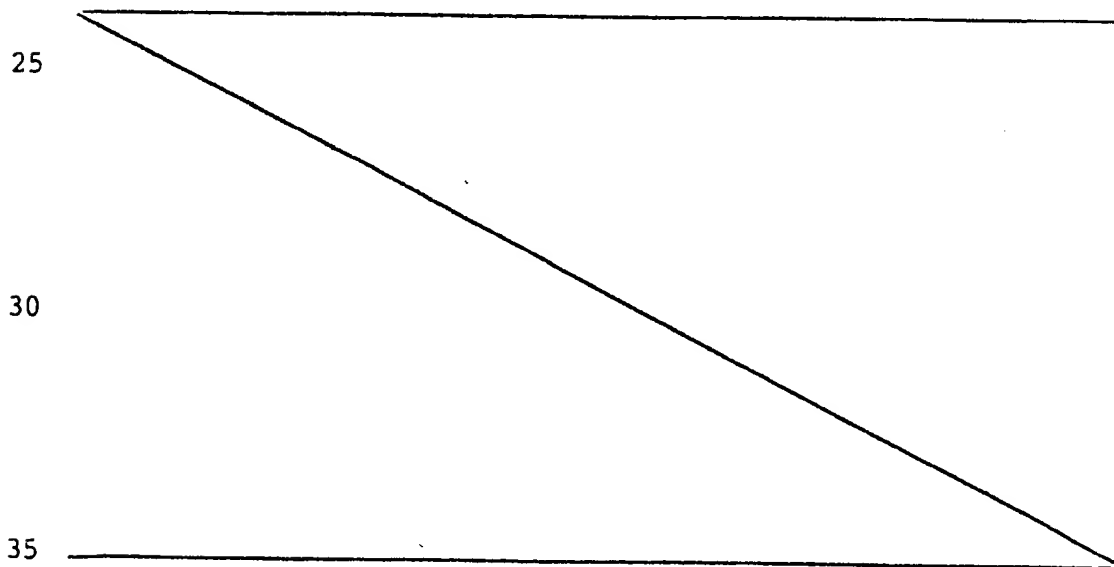
          The processor shown in Figure 2 illustrates  
spray means 44 providing a single spray nozzle.  
Alternatively other types of spray means may be provided.  
15 For example, Figure 4 shows spray means 44a having two  
spray nozzles interconnected by a common conduit through  
spreader 42 to spray low viscosity liquid onto the films  
of material carried past spreader 42.

          Figure 4 also illustrates an alternate  
20 arrangement of a mixing passage embodying the invention  
providing blocking member 70 associated with housing 16  
and extending into the channel between spray means 44a  
and end wall 38 to partially block, collect and mix the  
material and liquid at an upstream surface of blocking  
25 member 70. Following the mixing upstream of blocking  
member 70, the mixture is dragged past blocking member 70  
toward the end wall. In a preferred  
embodiment of the processor illustrated in Figure 4,  
blocking member 70 comprises a second spreader extending  
30 into the channel and providing a clearance between each  
of the opposed channel side walls and the second  
spreader. At least a portion of the mixture collected  
upstream of the spreader is dragged through the  
clearances by the rotating side walls of the channel and  
35 spread as films on the side walls to be carried toward  
the end wall in a manner similar to that described above

1 with respect to spreader 42. Optional port 72 may be  
provided through the housing between blocking member 70  
and the end wall, to provide venting of the void formed  
in the passage between the films and downstream of  
5 blocking member 70.

The apparatus and methods of the present  
invention may be utilized to mix a low viscosity fluid  
with a viscous material to form either a homogeneous or a  
heterogenous mixture. Anticipated commercial uses  
10 include the mixing of such low viscosity liquids as  
reactants, monomers, initiators or inhibitors with  
viscous materials for polymerization or copolymerization,  
as well as the injection of an inert stripping fluid such  
as water or pentane into polymer melts such as  
15 polystyrenes for purification of the polymer by vacuum  
stripping.

It should be understood that the invention is  
not intended to be limited by what has been particularly  
shown and described but only as indicated in the  
20 accompanying claims. Accordingly, the invention presents  
to the art novel, energy efficient rotary processors and  
methods for mixing low viscosity liquids with viscous  
materials.



1

CLAIMS

1. A method for mixing a low viscosity liquid with a viscous material comprising:

5

A. introducing the viscous material at a feed point to one or more substantially annular mixing zones each defined by two rotatable, substantially circular walls, a stationary surface coaxial with the circular walls and enclosing the mixing zone, an end wall positioned downstream of and a major portion of the circumferential distance about the zone from the feed point, and a spreader positioned between the feed point and the end wall;

15 B. rotating the circular walls of each mixing zone at substantially equal velocities, in the same direction from the feed point toward the end wall, so that the material introduced at the feed point is dragged forward by the circular walls from the feed point toward the end wall of each mixing zone;

20 C. partially blocking upstream of the spreader the downstream movement of the dragged-forward material in each mixing zone and spreading the blocked material at the spreader on the circular walls of each mixing zone so that at least a portion of the material is dragged downstream past the spreader as films on the circular walls and so that a void is formed downstream of the spreader and between the films;

30 D. spraying the low viscosity liquid from a point within the void in such a way that the low viscosity liquid is deposited on and carried downstream with the films of viscous material;

E. blocking at the end wall the downstream movement of the material and liquid and collecting the material and liquid so that a recirculating pool of material and liquid is formed at

35

1 the end wall in which the liquid is mixed with the  
material;

F. discharging the mixture of the  
material and the liquid from the mixing zone at a  
5 discharge point near the end wall.

2. A method according to claim 1 further  
comprising the step of containing within the void a zone  
of saturated vapor of the low viscosity liquid at a  
10 partial pressure substantially equal to the vapor  
pressure of the liquid at the processing temperature so  
that the liquid sprayed into the void vaporizes to be  
condensed on the films of material as well distributed  
fine droplets.

15

3. A method according to claim 1 further  
comprising the step of partially blocking the downstream  
movement of the material and liquid and collecting the  
material and liquid at a mixing point between the  
20 spraying point and the end wall so that an additional  
recirculating pool of material and liquid is formed at  
the mixing point in which the liquid is mixed with the  
material.

4. A method according to claim 3 wherein the  
25 mixing point is provided by an upstream surface of a  
second spreader and further comprising the step of  
dragging the mixture downstream past the second spreader  
so that at least a portion of the mixture is respread on  
the circular walls as films and so that a second void is  
30 formed downstream of the second spreader and between the  
respread films.

5. A method according to claim 1 wherein the  
sequence of steps A-F are carried out two or more times  
35 in series.



1           6.    A method according to any one of the  
preceding claims further comprising the step of  
controlling the temperature of the material during at  
least a portion of the mixing process.

5

7.    A method for devolatilizing a viscous  
material to remove one or more impurities comprising:

          A.    introducing the viscous material  
containing the impurities at a feed point to one more  
10 substantially annular mixing zones each defined by two  
rotatable, substantially circular walls, a stationary  
surface coaxial with the circular walls and enclosing the  
mixing zone, an end wall positioned downstream of and a  
major portion of the circumferential distance about the  
15 zone from the feed point, and a spreader positioned  
between the feed point and the end wall;

          B.    rotating the circular walls of each  
mixing zone at substantially equal velocities, in the  
same direction from the feed point toward the end wall,  
20 so that the material introduced at the feed point is  
dragged forward by the circular walls from the feed point  
toward the end wall of each mixing zone;

          C.    partially blocking upstream of the  
spreader the downstream movement of the dragged-forward  
25 material in each mixing zone and spreading the blocked  
material at the spreader on the circular walls of each  
mixing zone so that at least a portion of the material is  
dragged downstream past the spreader as films on the  
circular walls and so that a void is formed downstream of  
30 the spreader and between the films;

          D.    spraying from a point within the void  
a low viscosity, low boiling carrier liquid selected to  
act as a devolatilizing aid to remove one or more of the  
impurities contained in the viscous material, in such a  
35 way that the carrier liquid is deposited on and carried  
downstream with the viscous material, and in a proportion

1 relative to the material sufficient to remove at least a  
portion of the impurities contained in the material;

E. blocking at the end wall the  
downstream movement of the material and carrier liquid  
5 and collecting the material and carrier liquid so that a  
recirculating pool of material and carrier liquid is  
formed at the end wall in which the carrier liquid is  
mixed with the material to a degree sufficient to aid  
devolatilization of at least a portion of the impurities  
10 from the viscous material;

F. discharging the mixture of the  
material and the carrier liquid from the mixing zone at a  
discharge point near the end wall; and

G. devolatilizing the mixture to separate  
15 the carrier liquid and at least a portion of the  
impurities from the viscous material.

8. A method according to claim 7 further  
comprising the step of containing within the void a zone  
20 of saturated vapor of the carrier liquid at a partial  
pressure substantially equal to the vapor pressure of the  
carrier liquid at the processing temperature so that the  
carrier liquid sprayed into the void vaporizes to be  
condensed on the films of material as well distributed  
25 fine droplets.

9. A method according to claim 7 further  
comprising the step of partially blocking the downstream  
movement of the material and carrier liquid and  
30 collecting the material and carrier liquid at a mixing  
point between the spraying point and the end wall so that  
an additional recirculating pool of material and carrier  
liquid is formed at the mixing point in which the carrier  
liquid is mixed with the material.

1           10. A method according to claim 9 wherein the  
mixing point is provided by an upstream surface of a  
second spreader and further comprising the step of  
5   dragging the mixture downstream past the second spreader  
to that at least a portion of the mixture is respread on  
the circular walls as films and so that a second void is  
formed downstream of the second spreader and between the  
respread films.

10           11. A method according to claim 7 wherein the  
sequence of steps A-G are carried out two or more times  
in series.

15           12. A method according to any one of claims 7  
to 11 further comprising the step of controlling the  
temperature of the material during at least a portion of  
the devolatilizing process.

20           13. Apparatus for mixing a low viscosity  
liquid with a viscous material comprising:

A. a rotatable element comprising a rotor  
carrying one or more annular mixing channels, each  
channel having opposed side walls extending radially  
inwardly from the rotor surface;

25           B. a stationary element having a coaxial  
closure surface cooperatively arranged with the channels  
to provide one or more enclosed mixing passages, each  
mixing passage having an inlet, a member providing an end  
wall for the passage and spaced apart from the inlet, an  
30   outlet near the end wall, and a spreader extending into  
the channel between the inlet and the end wall and  
providing a clearance between each of the opposed side  
walls of the channel and the spreader, all associated  
with the stationary element and arranged so that viscous  
35   material fed to the inlet is dragged forward by the  
rotating side walls past the spreader so that at least a

1 portion of the material is dragged through the clearance  
between the walls and the spreader and spread as films on  
the side walls to be collected and mixed at the end wall  
and discharged through the outlet, and so that a void is  
5 formed downstream of the spreader and between the films;

C. spray means arranged to spray the low  
viscosity liquid from a point within the void in such a  
way that the liquid is deposited on and carried  
downstream with the films of viscous material toward the  
10 end wall to be mixed with the viscous material.

14. Apparatus according to claim 13 wherein  
the spray means comprises at least one spray nozzle  
positioned in the void at or near a downstream surface of  
15 the spreader and a conduit through the spreader  
interconnecting the nozzle and a liquid supply means.

15. Apparatus according to claim 13 further  
comprising pressure sealing means to control leakage from  
20 the void of vapors of the low viscosity liquid and to  
permit the containment within the void of a zone of  
saturated vapor of the low viscosity liquid at a partial  
pressure substantially equal to the vapor pressure of the  
liquid at the processing temperature so that liquid  
25 sprayed into the void vaporizes to be condensed on the  
films of material as well distributed fine droplets.

16. Apparatus according to claim 13 further  
comprising a blocking member associated with the housing  
30 and extending into the channel between the spray means  
and the end wall to partially block, collect and mix the  
material and liquid at an upstream surface of the  
blocking member before the mixture is dragged past the  
blocking member toward the end wall.

1           17. Apparatus according to claim 16 wherein  
the blocking member comprises a second spreader providing  
a clearance between each of the opposed channel side  
walls and the second spreader, at least a portion of the  
5 mixture being dragged through the clearance and respread  
as films on the side walls.

          18. Apparatus according to claim 13 further  
comprising at least one material transfer groove  
10 interconnecting an adjacent pair of passages for  
in-series operation, each material transfer groove being  
formed in the closure surface and extending from a point  
near the end wall of the more upstream passage to the  
more downstream passage and providing the outlet for the  
15 more upstream passage and the inlet for the more  
downstream passage.

          19. Apparatus according to any one of claims  
13 to 18 further comprising means for controlling the  
20 temperature of the material in at least a portion of the  
apparatus.

          20. Apparatus for devolatilizing a viscous  
material to remove one or more impurities comprising:

25           A. a rotatable element comprising a rotor  
carrying one or more annular mixing channels, each  
channel having opposed side walls extending radially  
inwardly from the rotor surface;

          B. a stationary element having a coaxial  
30 closure surface cooperatively arranged with the channels  
to provide one or more enclosed mixing passages, each  
mixing passage having an inlet, a member providing an end  
wall for the passage and spaced apart from the inlet, an  
outlet near the end wall, and a spreader extending into  
35 the channel between the inlet and the end wall and  
providing a clearance between each of the opposed side

1 walls of the channel and the spreader, all associated  
with the stationary element and arranged so that viscous  
material fed to the inlet is dragged forward by the  
rotating side walls past the spreader so that at least a  
5 portion of the material is dragged through the clearance  
between the walls and the spreader and spread as films on  
the side walls to be collected and mixed at the end wall  
and discharged through the outlet, and so that a void is  
formed downstream of the spreader and between the films;

10 C. spray means arranged to spray from a  
point within the void a low viscosity, low boiling  
carrier liquid selected to act as a devolatilizing aid to  
remove one or more of the impurities contained in the  
viscous material, in such a way that the carrier liquid  
15 is deposited on and carried downstream with the viscous  
material toward the end wall to be mixed with the viscous  
material, and in a proportion relative to the viscous  
material sufficient to remove at least a portion of the  
impurities contained in the material; and

20 D. means to devolatilize the mixture to  
separate the carrier liquid and at least a portion of the  
impurities from the viscous material.

21. Apparatus according to claim 20 wherein  
25 the spray means comprises at least one spray nozzle  
positioned in the void at or near a downstream surface of  
the spreader and a conduit through the spreader  
interconnecting the nozzle and a carrier liquid supply  
means.

30  
22. Apparatus according to claim 20 further  
comprising pressure sealing means to control leakage from  
the void of vapors of the carrier liquid and to permit  
the containment within the void of a zone of saturated  
35 vapor of the carrier liquid at a partial pressure  
substantially equal to the vapor pressure of the carrier

1 liquid at the processing temperature so that carrier  
liquid sprayed into the void vaporizes to be condensed on  
the films of material as well distributed fine droplets.

5 23. Apparatus according to claim 20 further  
comprising a blocking member associated with the housing  
and extending into the channel between the spray means  
and the end wall to partially block, collect and mix the  
viscous material and carrier liquid at an upstream  
10 surface of the blocking member before the mixture is  
dragged past the blocking member toward the end wall.

24. Apparatus according to claim 23 wherein  
the blocking member comprises a second spreader providing  
15 a clearance between each of the opposed channel side  
walls and the second spreader, at least a portion of the  
mixture being dragged through the clearances and respread  
as films on the side walls.

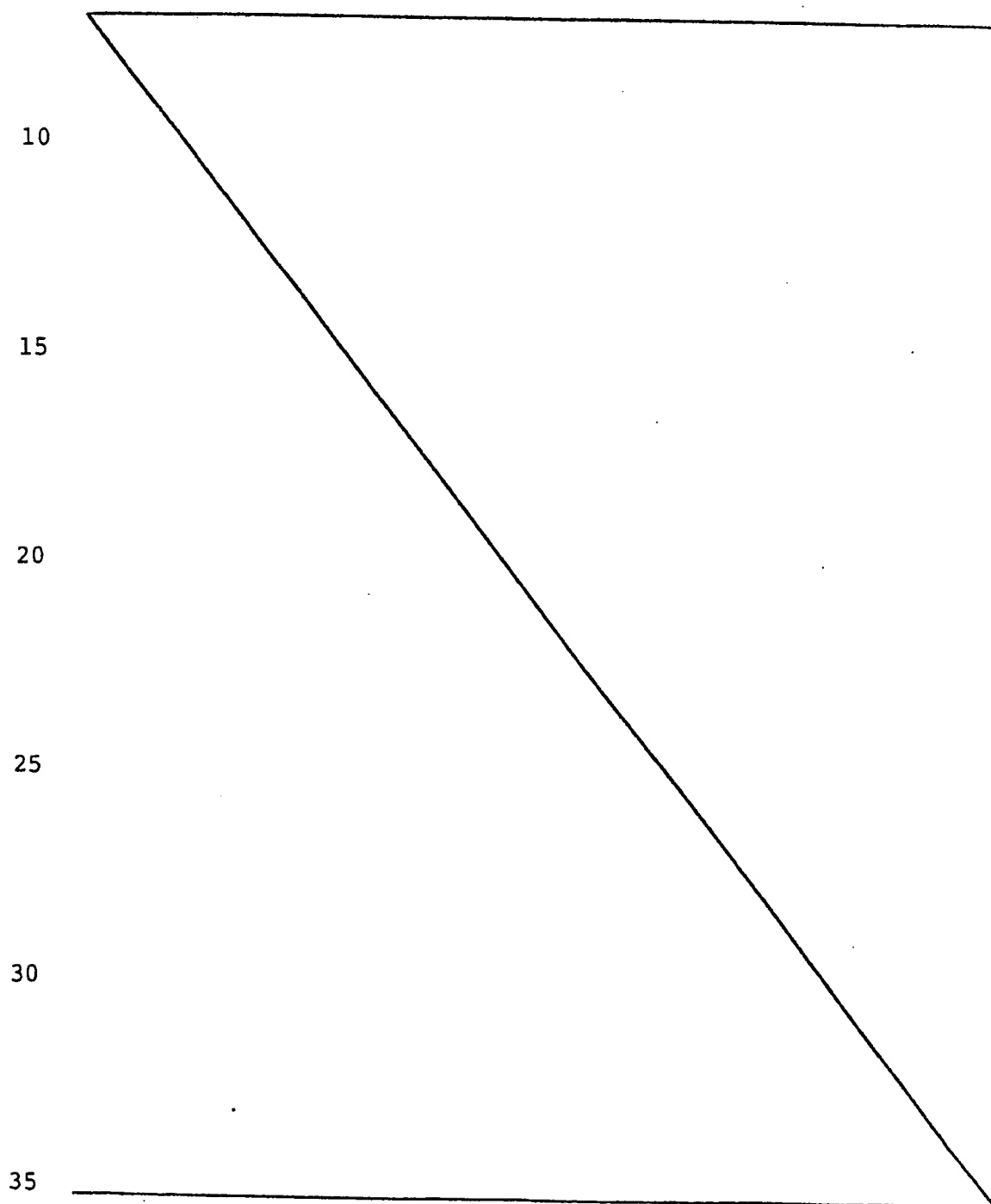
20 25. Apparatus according to claim 20 further  
comprising at least one material transfer groove  
interconnecting an adjacent pair of passages for  
in-series operation, each material transfer groove being  
formed in the closure surface and extending from a point  
25 near the end wall of the more upstream passage to the  
more downstream passage and providing the outlet for the  
more upstream passage and the inlet for the more  
downstream passage.

30 26. Apparatus according to any one of claims  
20 to 25 further comprising means for controlling the  
temperature of the material in at least a portion of the  
apparatus.

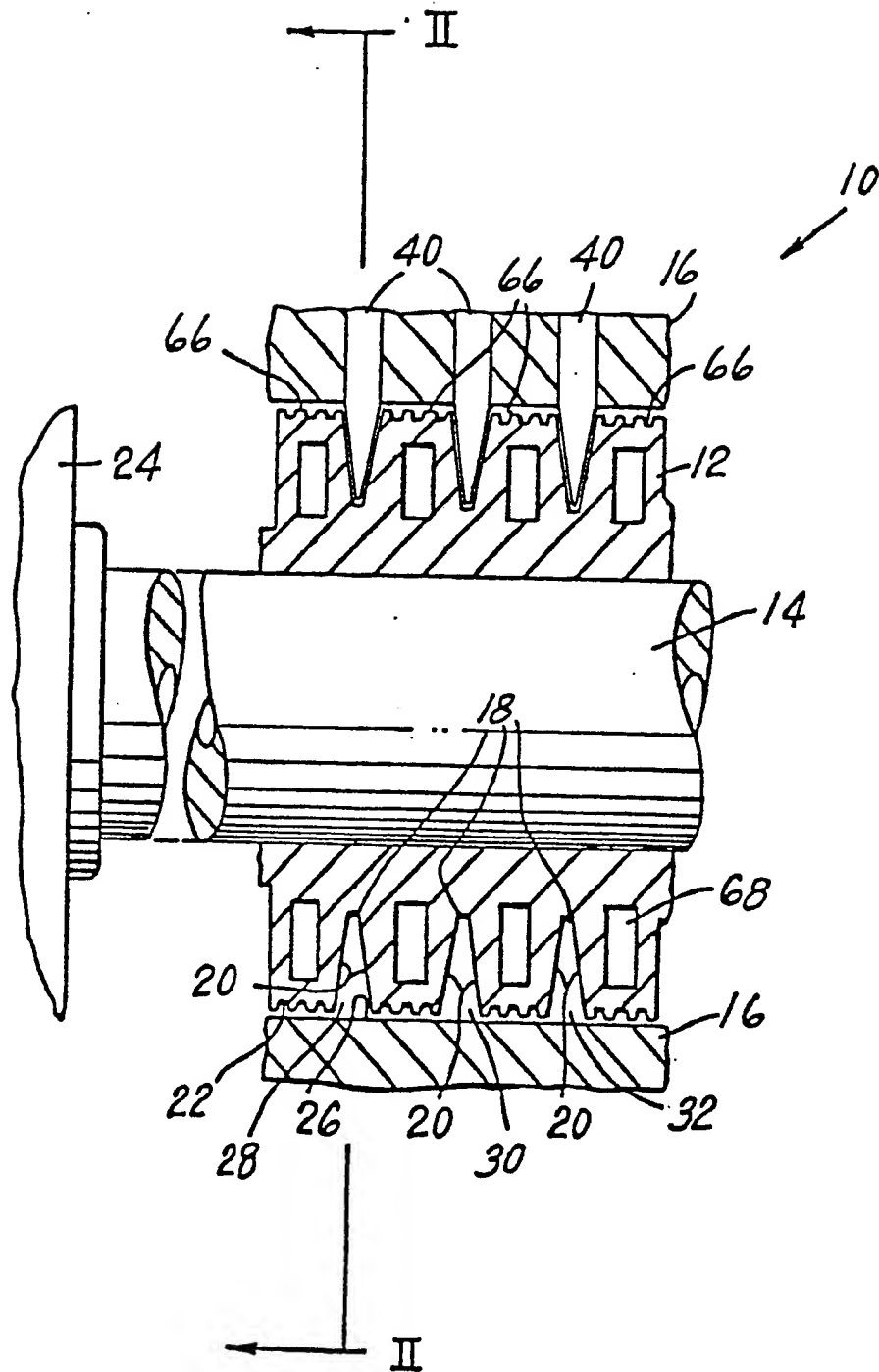
35 27. Apparatus for processing viscous material  
constructed arranged and adapted to operate substantially

1 as hereinbefore described with reference to the  
accompanying drawings.

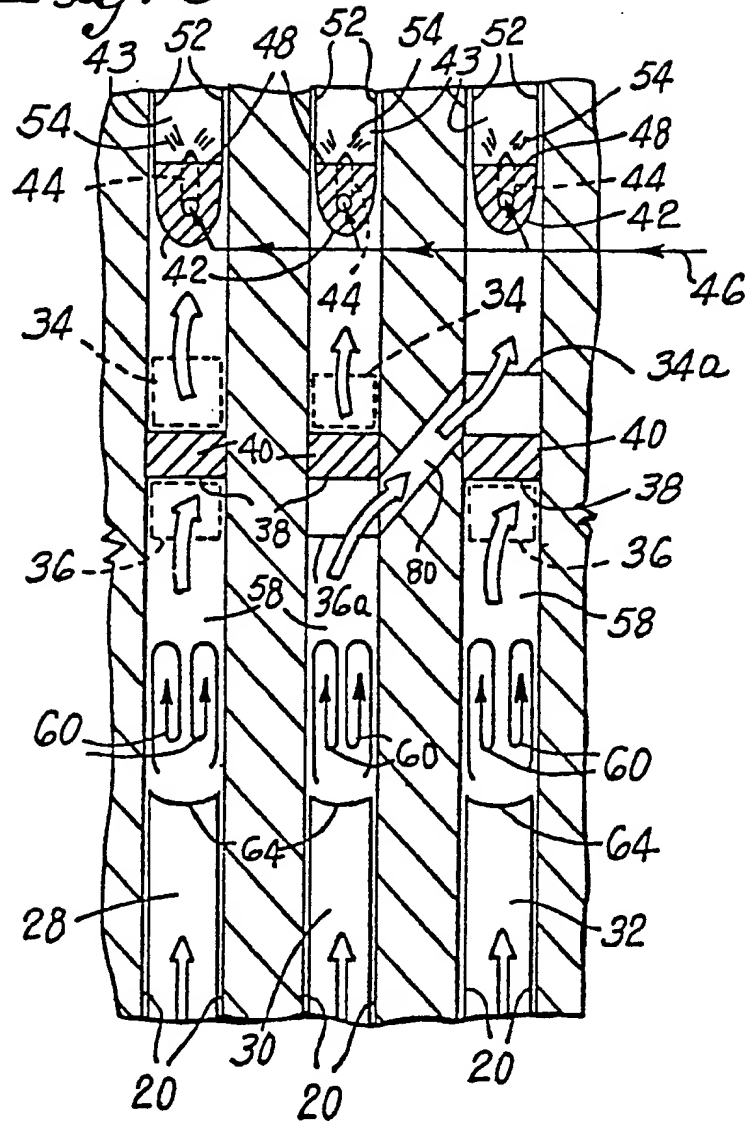
28. A method for processing viscous materials  
5 substantially as hereinbefore described with reference to  
the accompanying drawings.

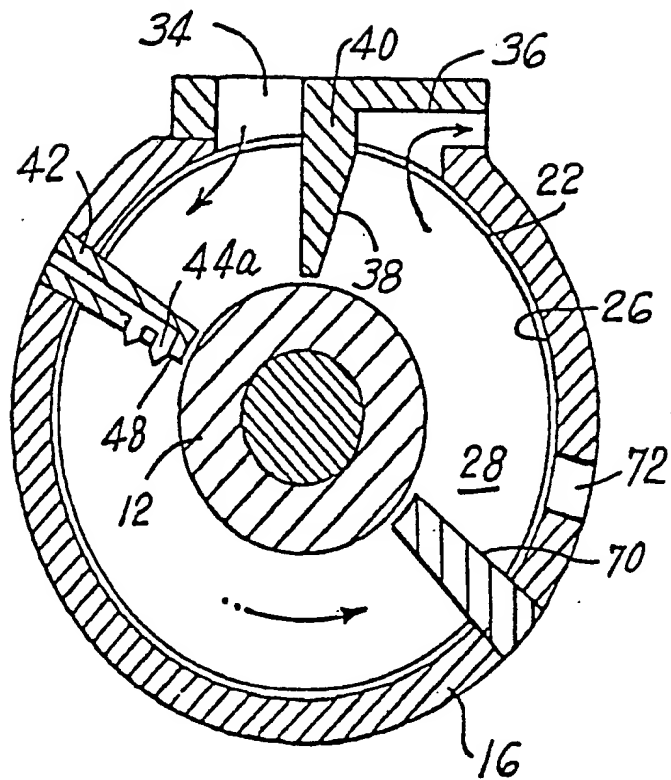




*Fig. 1*



*Fig. 3*

*Fig. 4*

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